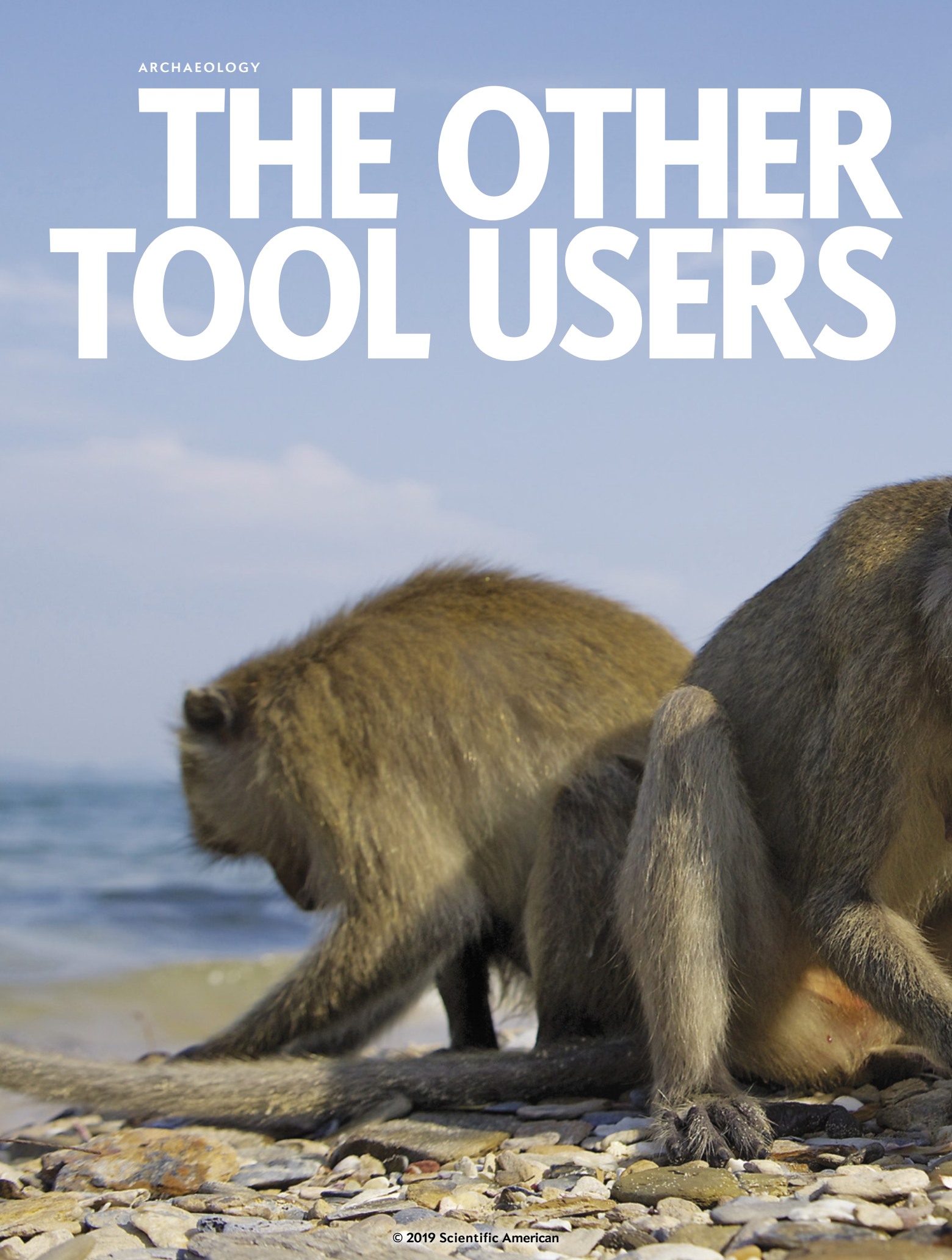
ARCHAEOLOGY

THE OTHER TOOL USERS



Excavations of stone tools left behind by nonhuman primates are illuminating the origins of technological innovation

By Michael Haslam

WILD BURMESE long-tailed macaques use stone tools to open shellfish on a beach in Thailand.

THE TIDE IS RISING FAST, BUT THE MONKEYS don't seem to mind. They bicker and loll on the rocks and mangroves farther up the shore, munching quietly on an oyster or enjoying a gentle grooming. The younger ones make a game of jumping from a tree branch into the warm, clear sea below. Like everyone along this coastal stretch of rural Thailand, they live in tune with the daily tidal rhythms.

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I, however, am quite concerned about the incoming water. It's a balmy December day in 2013, and I'm crouched on the beach beside a neat square hole, reaching as far down as I can to scrape out another trowel-full of damp sand. The hole is only half a meter on each side, but it has taken hours to dig, ever since the overnight high tide receded. Careless movement will collapse the entire thing in on itself, which means that rushing is not an option.

This is an archaeological dig, and it looks much like you might imagine, with buckets, sieves, strings, levels, collecting bags and measuring tapes strewn about. Yet the ancient objects that drew me here to the small island of Piak Nam Yai in Laem Son National Park are not typical archaeological finds. I am not looking for coins, or pottery, or the remains of an old settlement, or long-lost human culture. Instead I am after bygone traces of the monkey culture that is on full display up the beach.

I am, at least itinerantly, a primate archaeologist: I use traditional archaeological methods to understand the past behavior of a variety of primate species. To be honest, the image that I get when I use this phrase is of Dr. Cornelius, the chimpanzee in the original 1968 film *Planet of the Apes* who controversially unearths evidence that humans were not always mute beasts. He is charged with heresy for his discovery, and although it is not discussed in the film, I strongly suspect that he also loses his funding. Cornelius resonates with me because my colleagues and I have recently been building a new scientific field that directly mirrors his work. For more than 150 years the term "archaeology" has described the scientific study of physical remains of a strictly human past. In that time, there have emerged a multitude of subfields focused on specific times, places or methods, but they have all had one central theme: understanding people. Nonhuman animals were a part of archaeological study but only as food, transport, pets or parasites. They orbited our world.

Certainly this focus has produced extraordinary achievements. For instance, in 2015 Sonia Harmand of Stony Brook University and her team stretched the known record of human behavior back to more than three million years ago when they found stone tools left by a distant ancestor at the site of Lomekwi in Kenya. (The fact that these objects are made of stone is not a coincidence, by the way. For the vast majority of that multimillion-year record, stone tools have been the only cultural artifacts that have survived to guide our interpretations of our origins—objects made from more perishable materials have been lost to time.)

By turning the spotlight on our closest evolutionary relatives—monkeys and apes—primate archaeology aims to build a richer framework for understanding this long history of human technological development. Humans and our direct ancestors are primates, too, of course, and illuminating our own evolutionary journey is still a central goal of this research. Placing the surprisingly complex rise of human technology into its wider biological context will give us a better grip on those features that derive from our shared primate heritage and those that are truly unique to us.

ABSENCE OF EVIDENCE

A BIG PART OF WHY archaeologists have traditionally focused exclusively on the recovery of human material culture is that for a long time, researchers thought that humans alone use and produce tools. Primatologist Jane Goodall was the first to show otherwise through her studies of chimpanzees in the 1960s. Anthropologist Louis Leakey had been discovering a variety of fossil humans and stone tools in ancient lakeshore environments in eastern Africa, and he wanted to know what kinds of activities the human ancestors there might have engaged in. So Leakey recruited Goodall and sent her to what is now Gombe Stream National Park, on the eastern shore of Lake Tanganyika in Tanzania, to see how the chimpanzees there behaved. Although her eventual discoveries had little to do with the actual lake, her observations of chimpanzees making and using tools to obtain food forever changed our perception of primate abilities. But the Gombe chimps (*Pan troglodytes schweinfurthii*) use tools only made from plants, which last a matter of weeks in the tropical climate. The mismatch in survival between the million-year-old stone tools found in abundance by Leakey and the sticks and grass tools found by Goodall was stark.

Fortunately, chimpanzees are an inventive lot, and in the 1970s researchers discovered several groups of the western subspecies (*Pan troglodytes verus*) using stone tools to crack open forest nuts. Genetic evidence suggests that this subspecies split from the main, central chimpanzee population perhaps half a million years ago. Given the lack of stone tool use among central or eastern chimpanzees (as seen at Gombe)—or among their sister species, bonobos (*Pan paniscus*)—it seems likely that the western population independently invented stone use since that time.

That discovery raised key questions about the origins of stone tools. Our common ancestor probably used plant tools, just as wild chimpanzees and bonobos, as well as orangutans and gorillas, do. But why did only a very few branches of the family tree look to stone as a

IN BRIEF

Archaeologists have traditionally focused solely on the recovery of material culture belonging to members of the human family. **But some nonhuman primates,** as well as other species, use tools. **In recent years** researchers have begun to unearth the archaeological records of these other creatures. **Such investigations** stand to elucidate the factors that governed the rise of human and nonhuman technology.

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raw material? Furthermore, wild chimps have a very limited range of uses for stones, based chiefly on the mechanical advantage gained by employing a hard rock to crack open a stubborn nutshell. Humans, on the other hand, used stones to develop everything from cutting tools to projectile tips, from jewelry to the pyramids of Egypt and Central America. Why do the technological trajectories of chimps and humans look so different?

With just two examples of stone tool technology, developed independently by humans and chimpanzees, the steps leading to its emergence are difficult to resolve. We cannot simply take what one subset of chimps do and map it onto our early ancestors, arguing that human technology arose from stone-tool-mediated nut cracking. It would make just as little sense to take what a subset of modern humans do and map it onto chimpanzee ancestors.

One of the main issues is that we have virtually no record of the evolution of chimpanzees. Mounting DNA evidence indicates that humans and chimps diverged from their common ancestor around seven million years ago. Yet the only known chimpanzee fossils are three teeth dating to around half a million years ago. And the oldest known chimpanzee tools are little more than 4,000 years old. As a result, knowledge of our ape siblings is stuck in something of an eternal present, with our view of them almost entirely derived from the past few decades. If we evaluated humans over the same short time frame, we would gain very sparse understanding of how our technologies emerged and changed throughout our evolution. If we had to guess, would we consider chopsticks or cutlery to best represent ancestral human eating tools? Is the PlayStation or Xbox the more primitive form of a human plaything? These questions may seem slightly absurd, yet scientists often fail to consider whether past chimps behaved anything like those we see now. Were they less technologically proficient? Or more so?

We have reached the end of anthropocentric archaeology; going forward, archaeology has all past behavior in its sights.

Another central concern is that a two-way comparison offers few clues as to why certain features developed in one lineage and not the other. For example, as early as the 1860s, English naturalist John Lubbock (who coined the terms "Paleolithic" and "Neolithic" for chapters of the Stone Age) suggested that primate nut cracking could be a simple precursor of the human tendency to break stones against each other to create sharp-edged flakes for cutting. If so, why do living chimpanzees not flake stones? Does the absence of this behavior stem from a lack of imagination, time or opportunity? Ideally we would have a much broader selection of case studies to test our hypotheses about the development of technology. This is where the monkeys I have been studying clamber to our rescue.

GAME OF STONES

BACK ON THE BEACH in Thailand, the bottom of the hole is now filling with water. It seeps in from the sides, threatening to undercut and destabilize the walls even further. I have rigged a boat pump to a car battery to keep the level down, but I am losing the battle. Finally, with the waves lapping at my toes, I carefully bring up a series of small volcanic rocks, each one bearing distinct scars and pits on their rough surface.

Thanks to work over the past decade by primatologists Suchinda Malaivijitnond of Chulalongkorn University in Thailand and Michael Gumert of Nanyang Technological University in Singapore, we now know that wild Burmese long-tailed macaques (*Macaca fascicularis aurea*) on Piak Nam Yai and other islands along the coast of the Andaman Sea regularly use stone tools. The behavior extends north from Thailand into Myanmar, where it was first described in the 1880s by Alfred Carpenter, a British sea captain. That report seems to have gone largely unnoticed, though, and it was only in early 2005, during surveys to assess the effects of the devastating Indian Ocean tsunami of 2004, that macaque tool use was rediscovered.

The macaques' use of stones seems to be entrenched, given the similarity of observations from the 19th and 21st centuries. Once the tide goes out, the monkeys come down from the interior forests of their island. They select roughly hand-sized stones from those lying on the shore and use them to strike and remove the upper shell of oysters attached to the now exposed rocks. They typically need only five or six strikes to open each oyster, and they carry around the same tool to use over and over again. In extreme cases, my team has seen them use one stone hammer to crack and consume more than 60 oysters in a row.

Oysters are not the only food for which the macaques need a utensil. Intertidal zones such as this one are rich with animal life. Although the macaques prefer oysters, they are also on the lookout for marine snails and crabs. Unlike oysters, these prey can and do run away, so the monkeys gather them up and take them to a nearby flat rock. They then find a much larger stone than the ones used for oyster pounding—the largest weigh several kilograms—and use it to crush their food against the flat rock, which serves as an anvil. When the group is midfeast, the constant cracking and rapping sounds of stone on shell fill the air.

The end result of these low-tide grab-and-smash raids is a shoreline strewn with broken shells and battered stones. The monkeys select their tools with skill and persistence, using the pointed ends of small rocks to precisely hit the oysters and the large central areas of the bigger rocks to pound open snails. These two main patterns of behavior damage the tools in predictable ways, and my colleagues and I have shown that how a macaque tool was used (and therefore its potential target prey) can be determined from wear, which is readily distinguished from scars seen on naturally modified stones. It is this characteristic damage that I search for as I dig into the soft beach sands. The small volcanic rocks that I have rescued from the tides bear the oyster-processing marks. Although these artifacts do not push back the known antiquity of macaque tool use—the oldest ones date to just 65 years ago—they are the first monkey tools ever found through archaeological excavation.

CAPUCHINS AND CASHEWS

THESE MACAQUES are not the only monkeys that have left behind an archaeological record. Fast-forward to late 2014, and I am back beside a square hole, but this time there is no sea breeze to alleviate the heat. Surrounding me are the scrub forests and towering

sandstone plateaus of the semiarid Serra da Capivara National Park in northeastern Brazil. A team of undergraduate students from a university in nearby São Raimundo Nonato is digging, while Tiago Falótico and Lydia Luncz—my primatologist postdoctoral researchers at the time—record the finds. Thankfully, there is no encroaching tide, just the occasional scorpion or spider objecting to us moving its leaf litter around.

We are here because the wild bearded capuchins (*Sapajus libidinosus*) that live in the park have proved themselves to be master technologists. In 2004 capuchin experts Dorothy Fragaszy of the University of Georgia and Elisabetta Visalberghi of the Institute of Cognitive Sciences and Technologies in Italy reported that they had observed wild capuchins in a similar habitat some 200 miles away using stone tools. Now we know that capuchins at a wide range of sites in Brazil's interior select and use heavy stones to break open the tough shells of the local nuts and fruits in a manner that superficially resembles the behavior of western chimpanzees. The capuchins in Serra da Capivara National Park are especially creative with their tools, however. In addition to cracking open nuts and fruits, they also use rocks to penetrate the soil and dig down in search of burrowing spiders and plant roots. In another parallel with their ape cousins, these capuchins also select and break off twigs and then bite them to size and strip the leaves to make probes that they use to hunt hard-to-reach prey, such as lizards hidden in crevices.

One food in particular has our eye during the excavation. Cashew trees are indigenous to this area of Brazil, although they are now grown commercially worldwide. Their nut is nutritious and tasty, but fresh cashews have a caustic liquid in their shell that painfully burns the skin. So the capuchins use heavy stone hammers to break into the nuts. Their tactic is effective and, lucky for us, leaves telltale impact marks and dark cashew liquid all over the tools. By surveying and mapping capuchin stones that have accumulated over several years of use, we were able to find the pockets of the forest most intensively exploited by the monkeys. Because the soil, moisture and shade conditions that suit cashew tree growth have not changed significantly over the past few thousand years, we reasoned that the sites that are heavily trafficked today probably also saw a lot of capuchin activity in the past. Our excavations at a selection of these sites bore this notion out. We found at least four distinct phases of former monkey tool use, reflected in groups of buried stone hammers and anvils with clear damage from use. Bolstering our conclusion that these were capuchin tools, we found no signs of human activity, whether fire or pottery, or any of the kinds of stone tools people are known to make.

The oldest layer with capuchin tools dates back to between 2,400 and 3,000 years ago. These implements are therefore the oldest known nonhuman artifacts outside Africa, and they record the behavior of monkeys living well before the European invasion of the Americas. We did not find any evidence of ancient plant tool use from our excavations, but as is true for humans and other apes, this absence probably reflects the usual bias toward the survival of rocks over sticks.

Finding tools of another monkey species through archaeological excavation would have been reward enough for our efforts. But the Serra da Capivara National Park capuchins had a surprise in store for us. During the same field season, I filmed the monkeys breaking hammer stones against other rocks that were embedded into a large conglomerate block. They seemed to be aiming to create quartz dust, which they then licked or sniffed. Other researchers had observed this behavior before, but when I collected the broken pieces of rock and later excavated around the conglomerate block, I noticed something that had not been reported previously: the capuchins' rock shards bore an unmistakable resemblance to the stone flakes seen at some early human ancestor sites. Detailed analysis of the stones by another of my then postdocs at the University of Oxford, Tomos Proffitt, proved that we had found the first example of a nonhuman primate deliberately breaking stones and leaving behind sharp-edged flakes.

To be clear, the capuchins have not yet been observed using the sharp flakes that they create. In the wild, that behavior remains exclusively human, for now. But if repeated flaking of stone hammers can be an unintended by-product of an until now unimagined activity—creating dust for ingestion—then this finding raises substantial questions about parts of the early human archaeological record. Archaeologists have tended to assume that early humans deliberately smashed rocks to create sharp flakes for a specific purpose—cutting meat, for example. Given what we see in the capuchins, however, we must ask ourselves whether our ancestors three million years ago might have been similarly uninterested in those sharp rocks they were making. Did they, too, produce accidental flakes for a considerable time before latching onto the idea of picking them up and cutting things? Honestly, we do not know. But now we must at least consider the possibility. It would certainly smooth the pathway for the uptake of cutting as an innovation if there was already a known and reliable way to make the tools, with sharp edges moving conceptually from hazardous waste to valuable resource.

BEYOND PRIMATES

WHATEVER THE LESSONS for our own technological evolution, the finds from Brazil and Thailand mean that we now have archaeological records for three nonhuman primate lineages. It is worth pausing for a second to consider that fact. A mere decade ago we were learning of the existence of stone-tool-wielding wild monkeys. Now we have taken the first steps to trace that behavior back into deep time. The human line today forms only a quarter of the known primate archaeological records, albeit the best investigated portion by far.

In a recent paper, my colleagues and I suggested that we have reached the end of anthropocentric archaeology; going forward, archaeology has all past behavior in its sights. Some scholars may disagree with my contention that archaeology is just a method, applicable to any animal that leaves an enduring material record of its behavior, rather than something reserved for our own lineage. But the work of a small group of primate archaeologists has shown that it can open up new ways of viewing both our own evolutionary pathway and that of other species. Clearly, technology—the skilled and learned integration of material culture into our lives—is not a human-specific oddity. To evolve, it does not require language, or human-style teaching and cooperation, or even a large brain: the capuchins and macaques each have adult brains around 5 percent of the size of an adult human brain.

Moreover, stone tool use has emerged independently at least four times in relatively recent primate evolution: in coastal (macaque), lakeside (human), forested (chimpanzee) and semiarid (capuchin) environments. This diversity means we can reasonably expect that the same behavior has emerged repeatedly in the past,

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WILD BEARDED CAPUCHIN in Brazil uses a stone tool to open a cashew nut (*1*). Stones bearing the same distinctive scars and stains found on modern-day capuchin tools have been excavated at archaeological sites dating back as far as 2,400 to 3,000 years ago (*2*).

among many primate taxa, even if they no longer exhibit it or have gone extinct. Excitingly, if this scenario is true, the stone tools used by those taxa are still out there, waiting to be discovered.

There is no reason that we should stop at primates. In the past few years I have begun archaeological work with stone-tool-using wild sea otters on the West Coast of the U.S. in conjunction with ethologist Natalie Uomini of the Max Planck Institute for the Science of Human History in Jena, Germany, and other colleagues based at the Monterey Bay Aquarium and the University of California, Santa Cruz. We have learned, for instance, that the sea otters repeatedly return to favored places along the shoreline to break open shellfish, leaving behind damaged stones and large piles of discarded shells that could easily be mistaken for prehistoric human shell middens, or rubbish heaps. The feedback cycle between these durable landscape markers and their attraction for young animals learning to use tools may be a critical component of technological traditions among sea otters, much like the cycle between the prize cashew trees and the bearded capuchins.

Uomini and I have also conducted fieldwork on the archaeology of New Caledonian crows, which are famous for their sophisticated tool use and cognitive skills. New Caledonian crows regularly exploit specific locations on the landscape; once durable tool materials are added into the mix, we have all the necessary ingredients for the formation and survival of archaeological sites that allow us to reconstruct past animal behavior. Archaeology is an intrinsically interdisciplinary science, and adding ancient animal tool use to its research targets has been a satisfying—and even intuitive—step.

By chance, the recent rise of primate archaeology has coincided with the release of a new series of *Planet of the Apes* films. In them, our great ape relatives develop crude technologies that nonetheless rapidly surpass those known from wild animals in the real world. Even a simple composite spear, joining a sharp head to a separate shaft, requires a cognitive leap that appears absent in modern wild ape tools. Controlled use of fire and the wearing of jewelry are similarly extraordinary attributes of apes in these films, with no real-life examples of these behaviors known outside the human lineage.

But the technological apes we see on screen do not seem completely outlandish. They are even plausible. Western chimpanzees fashion simple, one-piece spears to attack smaller primates, just as capuchins do for lizards. William McGrew of the University of St. Andrews in Scotland, the most knowledgeable observer of chimp tool use and an early advocate for primate archaeology, once reported on an eastern chimp wearing a "necklace" made of knotted monkey skin. What else may take place when humans and their notebooks are not following these animals?

Human archaeology has emerged as a reliable source of insights into our development and diversity, a result of the efforts of thousands of scientists and billions of dollars over more than a century. As a reward for this effort, we now have millions of years of material culture that can act as a scaffold for our evolutionary speculations and scenarios. We are only at the starting line for the work to build a similar structure for nonhuman animals. But with an open mind, who knows what we might find? It is time to get digging that next square hole. SA

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MORE TO EXPLORE

Archaeological Excavation of Wild Macaque Stone Tools. Michael Haslam et al. in *Journal of Human Evolution,* Vol. 96, pages 134–138; July 2016.

Pre-Columbian Monkey Tools. Michael Haslam et al. in *Current Biology,* Vol. 26, No. 13, pages R521–R522; July 2016.

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FROM OUR ARCHIVES

The New Origins of Technology. Kate Wong; May 2017.

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